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POLYCERELLA ZOOBOTRYON.

By W. M. Smallwood.

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Contents.

I. External Characters.

In a previous paper (Smallwood, : 10), the general external features of this new species (Figure 1) were described; a part of that description follows, as I desire to present at this time a complete account of the morphological characters of the species — the histology as well as the anatomy.

Figure 1. Polycerella zoobotryon, dorsal view. Magnified 8 diameters.

"Polycerella zoobotryon is a small nudibranch, from 5 to 6 mm. in length and 1 1/2 mm. wide. The body is thickest just anterior to the branchial plumes. The shape is much as in Polycera — elongated, narrow, and about as high as broad. Body compressed, smooth, sloping rather abruptly from the branchial plumes

[1] Contributions from the Bermuda Biological Station for Research No. 24, and from the Zoölogical Laboratory of Syracuse University.

posteriorly until it merges into the long, pointed tail, which is much narrower and thinner than the body, and nearly one third the total length of the animal. The head is blunt and squarish. The tentacles are cylindrical, non-retractile, and one fourth the length of the rhinophores.

"The rhinophores are non-retractile, cylindrical, each having from three to six cup-like, equidistant folds on the posterior surface of its distal two-thirds.

"On the sides and dorsum of the body there are a number of short, clavate papillae, the tips of which are translucent. The number is not constant, but ranges from 16 to 19. Their distribution is as follows: — Of eight which are constant in position, two occupy the median plane, one of them behind the rhinophores about one sixth of the distance between base of branchial plumes and rhinophores, the other in front of the plumes about one fourth of the same distance. The remaining six are arranged in pairs near the median plane, one pair a little in front of the rhinophores and distant from each other about the thickness of a papilla; a second pair slightly in front of the posterior median papilla and a little further apartthan the an terior pair; the third pair nearly as much behind the plumes as the posterior median papilla is in front of them; these are still further from each other.

"In addition to these eight papillae, there are on the dorsum near its lateral margins from eight to eleven papillae. There are four on each side, or four on one side and five on the other, or, finally, five on one side and six on the other.

"The ground color is whitish, mottled with light brown arranged in irregular splotches. A less abundant darker brown is disposed in streaks across the lighter brown. The foot is white and without any color markings. Its margin, as well as the tips of the papillae, is translucent.

"The foot is smooth and slightly notched anteriorly. The mouth is T-shaped [or a vertical slit]. The anal opening is subcentral in position, and the excretory orifice is just posterior to it, both being surrounded by the gills.

"The gills consist of four or five more or less irregularly branching plumes.

"When at rest, the body is shortened, the tentacles drop back alongside the body, and the rhinophores lie on the dorsum. The papillae, which are constantly in motion when the animal is crawling, are bent dorsally when it is at rest, and are often knobbed. Under a low power lens one can see the long cilia in motion. The animal assumes a variety of positions while in this resting state, and it fre-

quently rests on its back. The foot may be fully expanded or much contracted. When the animal was placed in a weak solution of methylene-blue in sea-water, the cup-like folds on the rhinophores appeared as swellings, and after a few hours the lateral papillae and rhinophores were sloughed off.

"The eggs are laid in a cylindrical mass of jelly. The number varies from one hundred to three hundred in each mass. Each animal lays several egg-masses.

"The animals are very hardy, living in confinement for over six weeks."

II. The Systems of Organs.

The several systems of internal organs of Polycerella zoobotryon are so compactly grouped that it makes their interpretation difficult. The thin integument is rendered quite firm by the presence of numerous rod-shaped spicules. Between the integument and the various internal organs there is what remains unoccupied of the secondary body cavity, or coelom. In gross dissection one can recognize the anterior portion of the digestive system, consisting of the short buccal region, the dorsal suctorial bulb, and the ventral odontophore. The esophagus is distinguished with difficulty from the several reproductive ducts. The nerve collar of ganglia is so minute as to be made out only with fairly high powers of the dissecting microscope. Immediately posterior to the above organs lies the two-parted visceral mass, nearly concealed on the dorsal side of the liver and kidney chamber. The remaining portion of the secondary coelom is filled by the oval posterior visceral mass, which is composed of the liver and the hermaphroditic glands, bearing on their dorsal surface the stomach-intestine, kidney, and heart. The exact relationships of these several organs can be made out only by the aid of stained sections. Whole animals were fixed in either Hermann's fluid, Müller's fluid, or a picro-acetic mixture, the first two giving the best results. After remaining in Hermann's fluid for ten days, admirable adequately stained sections were secured, which have enabled me to make out some of the more perplexing conditions of the minute anatomy. Several specimens left in Hermann's fluid for three weeks were useless because they had become so brittle. Sections were made in the three principal planes of the body; these, together with dissections of several of the organs, have furnished the material for this study.

The observations on the living animal and the collection of the material were made in January, 1909, at the Bermuda Biological Station. I desire to express to the Director, Professor E. L. Mark, and to

the local authorities my appreciation of the courtesies extended to me during this time.

1. *The Integument.*

The integument consists of an outer epidermal layer, the cells of which vary much in appearance, and a dermal layer of loosely united

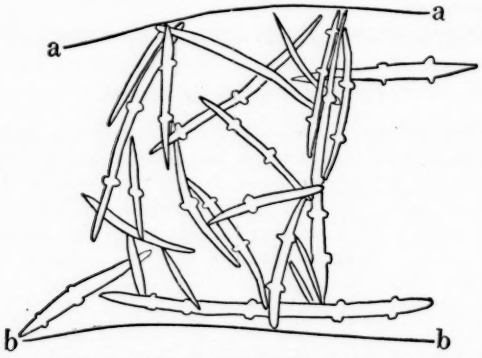

FIGURE 2. Spicules of the foot. *aa.bb.*, lateral margins of foot. Camera lucida, one inch ocular, and one-sixth inch objective. × 612.

connective-tissue cells. The epidermis is strongly ciliated on the surface of the foot, and the cilia can be traced up the sides of the body, although here they are much shorter; the dorsum is entirely destitute of cilia. The basal corpuscles at the base of the cilia are conspicuous. The pigment of the integument is deposited in roundish vaculated masses mostly at the inner ends of the epidermal cells. In the dorsum the epidermal cells are broad, short, and highly vacuolated, but in passing ventrally they gradually change to the elongated, cylindrical, richly cytoplasmic cells of the foot. The cells in the epidermis of the foot are fully twice as long as those on the back and are much crowded. The glands of the foot are simple, flask-shaped, multicellular glands having a small lumen. None of the epidermal cells of the foot appear to be glandular, as are many of those on the sides and dorsum, and on the rhinophores. The cells covering the gills constitute a thin columnar epithelium of a simple character. Histologically the foot is distinguished by a thicker epidermis, numerous glands, and a larger amount of connective tissue and irregularly shaped muscle cells.

The dermis contains numerous spicules, which vary in size from 15

to 60 micra in length and 1.4 to 3 micra in diameter. Each spicule is rounded at the ends and has a number of spiny enlargements. The largest spicules (Figure 2) are found in the foot. Their arrangement does not follow any plan, except that in the rhinophores and the several integumentary processes they are mostly parallel to one another.

2. *Anatomy of Digestive System.*

The mouth opens by a vertical slit directly into a short passage about 10 micra long, the buccal cavity (Figure 4, *cav. buc.*). The pos-

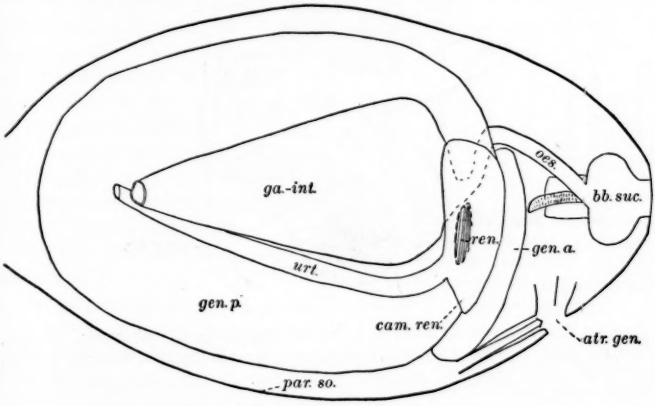

FIGURE 3. Diagram showing the general topographical relations of digestive, reproductive, and renal systems as seen from above. *atr.gen.*, genital atrium; *bb.suc.*, suctorial bulb; *cam.ren.*, kidney chamber; *ga.-int.*, stomach-intestine; *gen.a.*, anterior genital mass; *gen.p.*, posterior genital mass; *oes.*, esophagus; *par.so.*, body wall; *ren.*, kidney; *urt.*, ureter.

terior part of this passage expands to form the pharynx, into the posterior end of which open three hollow organs; ventrally the anterior end of the radula sac (*sac. rad.*); more dorsally, the esophagus (*oes.*); and still more dorsally, the cavity of the suctorial bulb (*bb. suc.*). The walls of the buccal cavity are largely composed of muscles and have a thickness of 12–15 micra. The dorsal portion of the buccal cavity is directly continuous with the enlarged suctorial bulb, the wall of whose fundus often attains a thickness of 30 micra. The posterior wall is not more than one half as long as the anterior. The distance

from the mouth opening to the most dorsal portion of the suctorial bulb is about 70 micra, the cavity of the bulb being 25 micra long (Figure 4). The suctorial bulb is often in contact with the nerve collar.

The radula is borne on a roundish muscular mass 13 micra in diameter. The radula sac is practically cylindrical and 12 micra in

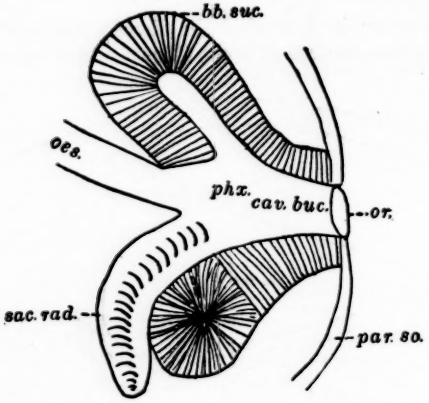

FIGURE 4. Diagram to show relation of organs to the pharynx. *bb.suc.*, suctorial bulb; *cav.buc.*, buccal cavity; *oes.*, esophagus; *or.*, mouth; *par.so.*, body wall; *phx.*, pharynx; *sac.rad.*, radula sac.

diameter (Figures 3, 4, *sac. rad.*); it projects 10 to 15 micra from the dorsal surface of the muscular mass. The total number of rows of teeth is 33–35, of which 18–20 are in the radula sac; in the posterior end of the sac are the beginnings of from 2–4 more rows. Each row contains eight teeth, the median tooth being absent, which gives the following formula 3–1–0–1–3. The first lateral tooth (Figure 5 l^1) is large and of a deep amber color; it is seven micra long and its greatest width is 1 1/2 micra. The lateral margin bears a wing-like projection 1/2 micron wide. The median edge of the distal half of the tooth is somewhat crenulated, producing the effect of a number of minute rounded teeth. This crenulated margin comes into close contact with the same region on the opposite tooth. Laterally there are three small teeth, the marginals; the first, though the largest of the three, is not more than 3 micra long and one micron wide; these

three marginals are not so deeply colored as the first lateral and have smooth outlines (Figure 5, l^{II}, l^{III}, l^{IV}).

Verrill ('80, p. 386) gives the characteristics of the radula of the genus Polycerella as follows: "Odontophore with six rows of teeth; median row absent; inner laterals large, curved, with three denticles; two outer rows much smaller, simple hook-shaped." Balch ('99, p. 150) gives for P. davenportii, "Radula almost as in P. emertonii Verrill ('80–81, p. 387; '82, p. 548), rhachidian tooth wanting; pleurae strongly hooked with accessory points, large; uncini two, sickle-shaped. Formula 2–1–0–1–2." The genus characters of the teeth should be modified, both in reference to the number of rows of teeth and to the shape of the outer laterals, so as to read as follows: — Odontophore with six to eight rows of teeth, median row absent, inner laterals large, slightly curved; outer rows much smaller, may or may not be curved.

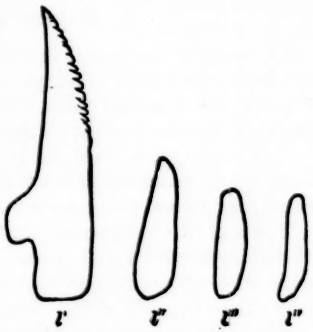

FIGURE 5. l^{I}, First lateral tooth; l^{II}, l^{III}, l^{IV}, second, third, and fourth lateral teeth drawn under one-sixth in. objective and one in ocular, with the aid of a camera lucida.

The esophagus (Figures 3, 4, *oes.*), as it arises from the dorso-posterior angle of the pharynx, has a diameter of 15 micra, which it retains until it expands into the stomach. It passes dorsally and posteriorly 100 micra, until it reaches the anterior surface of the posterior genital mass, where it turns abruptly to the right, entering the liver and passing through it for a short distance. As it emerges from the liver, it expands into the stomach-intestine (Figure 3, *ga.-int.*), the anterior extremity of which is beneath the renal chamber. The stomach-intestine is dorsal to the posterior hermaphroditic mass, and it reaches its greatest width near its anterior end, becoming gradually smaller until the anal opening is reached. There is no differentiation into stomach and intestine. The stomach-intestine receives two separate bile ducts, each connected with an independent bile sac. The duct of the smaller sac opens into the floor of the anterior end of the stomach-intestine, while that from the much larger bile sac opens into the posterior third of the organ.

A single pair of salivary glands, each about 28 micra long and 12 micra in diameter, opens into the posterior part of the pharynx just an-

terior to the origin of the esophagus. Each gland is flask-shaped, the neck of the flask being only one half the diameter of its fundus. These glands are partly covered by the nerve collar. In the wall of the buccal tube there are a considerable number of small glands that open into the buccal cavity.

3. *Histology of Digestive System.*

The walls of the buccal cavity, the pharynx, and the suctorial bulb are lined with a firm, thin layer of chitin, which is as deeply colored as the first row of lateral teeth. In the suctorial bulb and the posterior region of the pharynx the chitin is thinner and less deeply colored.

The esophagus is lined for its entire length with a ciliated epithelium, which makes up about one half of the thickness of the wall, the remaining portion being made up of connective-tissue and muscle cells.

The wall of the stomach-intestine is composed of a thick inner epithelial layer, with a well marked basement membrane, and a very thin outer layer of muscle and connective tissue, which in many places is only one or two cells thick. The cells in the epithelial layer are large, but from the basement membrane to the free surface the distance is noticeably short. The free end of each cell is highly vacuolated; the nucleus is basal and surrounded by fine cytoplasmic granules. These cells show little variation in their appearance throughout the length of the stomach-intestine.

The cells of the salivary glands are quite uniform in size, possibly a little longer in the larger part of the gland. Each cell is nearly cylindrical; its nucleus is basal, and its cytoplasm finely and homogeneously granular.

4. *The Liver.*

The liver occupies more than one half of the posterior visceral mass; its anterior two-thirds is surrounded by the hermaphroditic gland (see infra), which extends inward some distance, though the liver lobules, lying between the germinal follicles, extend in many places to the surface. The posterior third of the visceral mass is composed entirely of the liver, which is made up of numerous racemose lobes, giving it a rather loose appearance. The lobules of the liver open by minute connecting ducts into one or the other of the two bile sacs, the greater number opening into the posterior one, which is much the larger.

The cells are stained brown in Hermann's fluid, owing to the action of the osmic acid on the granules surrounding the numerous, rather large vacuoles contained in each cell. The free ends of the liver cells are irregular in outline and the cavity of the lobe, which in the granu-

lar part of the liver they surround, is filled with the same granular cytoplasmic mass containing vacuoles, the cell apparently breaking down after it becomes filled with the hepatic secretion. The gland cells are long and irregularly flask-shaped, the neck being attached to the basement membrane (Figure 6, *f*). The liver cells apparently regenerate the portion which breaks down, as there are no small basal cells and the large nucleus near the base of the cell is surrounded by numerous compactly arranged cytoplasmic granules. In the minute ducts leading into the bile sac the cells are more regular and much shorter (Figure 6, *e*), while those lining the bile duct itself are ciliated.

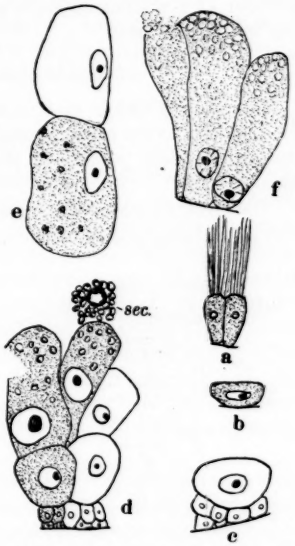

FIGURE 6. a, Ciliated cells from the mouth of the prostate duct; b, ordinary lining epithelial cells from prostate duct; c, cells from edge of glandular patch of prostate gland; d, cells of glandular patch of prostate gland; *sec.*, secretion; e, cells from duct leading from liver lobules; f, liver cells. All drawn with camera lucida, one inch ocular, and one-twelfth inch oil immersion objective. × 612.

5. *The Kidney.*

The nephridial organ (Figure 3, *ren.*) covers the upper surface of that portion of the posterior visceral mass which lies to the right of the esophagus and just anterior to the stomach. It does not extend down over the right side and usually does not exceed 40 micra in width. It consists of an irregular number of tubules immediately ventral to the pericardium. The cells are polygonal, their free ends being mostly transparent and apparently without concretions. A short duct connects the kidney with the real chamber (*cam. ren.*), which is a large bilobed sac. The dorsal lobe is 80 micra long, being much longer than the ventral lobe (50 micra). This large sac, 90 micra wide and 70 micra deep in its greatest extent, lies over the esophagus and projects beyond the anterior margin of the posterior genital mass (Figure 3, *com. ren.*). On the floor of the renal chamber there is a fold which nearly fills the passage into the kidney and is covered with long cilia. There seems to be a minute pore

through the wall of the renal chamber, in the region of the ciliated fold, which opens into the pericardium. The ureter of the kidney (Figure 3, *urt.*) is a small duct of uniform diameter, which follows the right contour of the stomach-intestine, and opens ventral to, and slightly at the left of, the anus.

6. *The Heart and Blood Gland.*

The blood gland is an irregular compact mass of minute round cells lying dorsal to the suctorial bulb and anterior to the nerve collar. The enlarged middle portion of the oviduct is often partly imbedded in this gland.

The heart consists of an anterior ventricle and a posterior auricle, the latter being partly divided. The pericardial cavity is nearly filled by the distended heart, the walls of which (Figure 7) are composed of connective-tissue cells and branching cells, which are interpreted as the contractile tissue of the heart because they are so similar to the evidently contractile cells of the foot. The blood passes to the various parts of the body through irregular sinuses, there being no clearly defined blood vessels apparent in my preparations. The fact that the cavities of the gills open directly into the secondary coelom is submitted as further evidence that there are no well defined blood vessels.

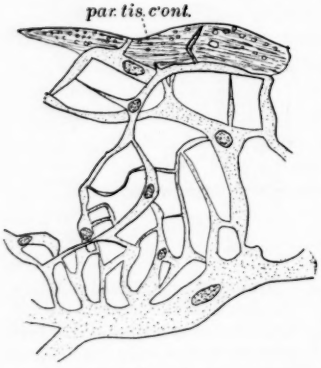

FIGURE 7. Edge of the ventricle of the heart showing the branching muscular cells. *par.tis.c'ont.*, connective-tissue wall. Camera lucida, one inch ocular and one-twelfth inch oil-immersion objective. × 612.

7. *Anatomy and Histology of the Reproductive System.*

The general features of the reproductive system are similar to those of most Nudibranchs. An hermaphroditic gland surrounds most of the liver, the two organs forming a conspicuous mass and nearly filling the posterior half of the secondary coelom. The hermaphroditic gland is usually designated as the posterior genital mass (Figure 3, *gen. p.*), the anterior genital mass (*gen. a.*) consisting of the albumen gland and the nidamental gland, which are united into one general body, and a prostate gland. The prostate gland lies posterior to the albumen

and nidamental glands and is more conspicuous on the left side. The posterior genital mass projects forward over the dorsal aspect of the anterior genital mass, concealing about one half of it as seen from above. Into the genital atrium open the oviduct and receptaculum seminis close to each other and also the penis sac. The detailed relation of each duct to the posterior and anterior genital masses and to the genital trium is presented in the following paragraphs.

Posterior Genital Mass.

In the posterior genital mass the arrangement of the male and female portions does not follow any definite plan; the ultimate tissue from which the germ cells are derived is a columnar epithelium composed of short and broad cells. This epithelium is much folded, forming follicles which project inward toward the center of the genital mass. A cross section of the genital mass shows many knob-like regions of eggs and sperms projecting almost to the center of the mass. Between such projections the liver cells of the anterior region often extend to the surface. Elsewhere in the anterior two thirds of this genital mass the germinal follicles envelope the liver in a layer of varying thickness. Each follicle is exclusively occupied by growing eggs or sperm cells.

The sperm cells in the material collected in January seem to be mostly in a state of maturity, but the eggs exhibit all stages of development. The maturing eggs show in a clear manner the relation of the nucleus to the formation of deutoplasm. All stages from the young ova to the mature egg are seen in the same section. In the young ovum the cytoplasm is evenly and finely granular; as it increases in size, small spherical droplets appear in close contact with the nuclear membrane; as growth continues several rows of droplets are distinguishable surrounding the nucleus. In the more mature egg finger-like masses of these droplets extend from the nucleus toward the periphery of the cell; these continue to become more numerous until the early finely granular condition is obliterated. In Hermann's fixation these deutoplasmic droplets are of all shades from a deep brown to black, indicating that at least a considerable portion of their substance is of a fatty composition. Müller's fixation followed by the usual iron haematoxylin gives the best differentiation for the study of the growth of the deutoplasm.

The numerous follicles open into an irregular series of minute ducts, which are finally collected into the common hermaphroditic duct. Before taking up the course of this duct, it is necessary to describe the

Anterior Genital Mass.

The anterior genital mass consists, as already mentioned, of the mucous gland, the nidamental gland, and the prostate gland. The first two unite to form a simple, conspicuous mass, each gland consisting of a number of foldings of a greatly thickened epithelium. After fixation in Müller's fluid, it is not easy to distinguish between these two glands, as their tubules have no constant position or shape; but after fixation in Hermann's fluid the resulting differentiation of the contents of the cells enables one to recognize at a glance the difference between the mucous and the nidamental regions. The actual space occupied by the mucous tubules is about one third as great as that occupied by the nidamental tubules, and the former are found mostly on the back and left sides, although a few extend into the center of the anterior genital mass and are there surrounded by the nidamental tubules. The outline of these combined glands is not regular, because some of the nidamental tubules project into the liver.

The nidamental cells are light colored after fixation in Hermann's fluid, the cell walls and nuclei being the only parts stained. In the animal thus fixed, the cells were congested, almost obliterating the lumen of the tubule, while in the one prepared in Müller's fluid and stained in iron haematoxylin the cytoplasm was faintly tinted and the cells shrunken so as to leave a large lumen. The mucous-gland cells which were fixed in Hermann's fluid were stained a deep brown, this color being due to the presence of numerous spherical bodies which fill the cell. This is the differential reaction which enables one to distinguish between these two glands. An animal that had recently discharged its mucous secretion was fixed in Müller's fluid and stained in haematoxylin followed by Bordeaux red. It showed the presence of a few small bodies in the distal ends of the flask-shaped cells. The large bodies took the haematoxylin stain in the center and the Bor deaux red around their periphery, while the small ones, just forming in the cytoplasm, took an exclusively Bordeaux red stain. It would seem, then, as if this secretion of the mucous cells was not a chemically homogeneous substance.

The prostate gland of *Polycerella zoobotryon* (Figure 8, *gl. prost.*), unlike that of *Polycera* (Pohl, :**05**, p. 434), is not folded, but consists of a large flask-like sac, the fundus of the flask being on the left side of the body, and its neck continuous with the prostate duct. The histology of this gland presents the following points of interest. The cells composing the main lining of the gland are elongated and mutually flattened; the nucleus is prominent, the cytoplasm finely and uni-

formly granular. For a short distance (from 15 to 20 micra) from the opening of the prostate duct, the cells (Figure 6, a) are narrow and elongated and carry long cilia, often 3 micra in length. The nucleus is much smaller than in any of the other cells, and the cytoplasm is coarsely granular.

The fundus of this flask-shaped prostate is largely occupied by the glandular area, a patch of thickened epithelium about 50 micra across. The cells in this glandular area are greatly enlarged, even at the edge of the patch, as shown in Figure 6, c. The conditions represented in Figure 6, d, show the number of layers of cells and their arrangement. At the bottom of the figure are some small basal cells which, together with a few larger ones, make up two rows similar in appearance to the cells regularly lining the gland (Figure 6, b), except that cells are frequently found in the second row which show the beginnings of the secretion so common in the distal cells of the glandular patch. The cells which cover the free surface of the glandular patch are greatly enlarged, especially in that part of each cell which is distal to the nucleus. The cytoplasm contains a number of spherical masses which, in preparations fixed in Hermann's mixture, are made up in part of 1 to 3 blackened corpuscles, the remaining portion of the mass taking no stain. The whole effect is like that of a vacuole containing differentiated bodies. After fixation in Müller's fluid, followed by haematoxylin, these masses are not apparent. That these minute bodies are secretions of the cell is abundantly shown by the fact that identical bodies nearly fill the prostate gland, and that special drops similar in form are often attached to the ends of these cells (Figure 6, d).

There are also found in the contents of the prostate gland numerous spermatozoa, and some bodies which it is difficult to explain from the present preparations. They are of about the size of the nuclei in the distal cells of Figure 6, d, but the detailed structure has degenerated to such an extent that one cannot recognize any relationship between them and other cells or parts of cells found in the organism. Pohl (: **05**, p. 434) finds abortive, undeveloped eggs in the ampulla of the sperm duct, which may be the key to the explanation in this case. The bodies appear much like pseudo cells in Hydra (Wager : **09**, Figure 14, Plate 3), which would mean that some undeveloped eggs had been set free and were being broken down in the prostate gland. A second explanation is equally probable: that the distal ends of the gland cells break off and the nucleus gradually undergoes degeneration. In only one instance, however, was there any evidence of such a breaking off of the tip end of the cell (see condition of one of the cells in Figure 6, d) ; but I am convinced that this is not the usual method of

discharging the secretion, or it would happen frequently and there would be more than this one instance in the several animals studied. But the large number of these bodies in the immediate vicinity of the glandular patch is very suggestive, and leads one to think that these bodies are escaped nuclei. The ends of some of the other cells in the glandular patch were frayed, as if the distal part had been lost.

8. *The Genital Ducts.*

1. The hermaphroditic duct emerges from the central and dorsal region of the posterior genital mass. As it leaves the genital mass it

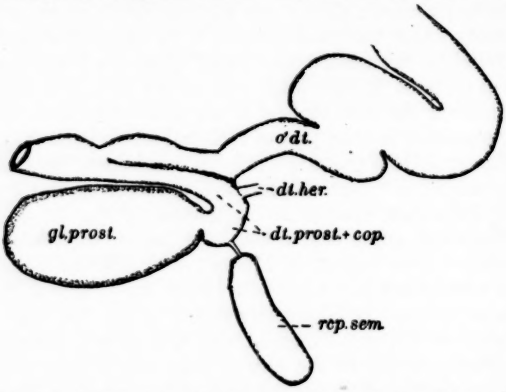

FIGURE 8. Drawing made partly from a dissection and partly from a reconstruction from sections, to show the prostate gland, its duct, the oviduct, and their relation to the hermaphroditic duct and receptaculum seminis. *dt.her.*, hermaphroditic duct; *dt. prost. + cop.*, prostate and copulation duct; *gl.prost.*, prostate gland; *o'dt.*, oviduct; *rcp.sem.*, receptaculum seminis.

turns, passing to the left side, and continues in this direction until it comes into contact with the body wall, where it turns forward. It then bends ventrally, and finally reaches the middle of the front surface of the anterior genital mass. Here it makes a sharp turn to the right, passing below the esophagus, and becomes partly enveloped by the nidamental gland. As the hermaphroditic duct emerges from the anterior right side of the anterior genital mass, it turns ventrally 25 micra and enlarges its diameter from 3 to 15 micra to form an ampulla. From the ampulla the duct courses dorsally over the right anterior surface of the nidamental gland and opens into the duct of the pros-

tate gland. A short distance before the formation of the ampulla, the hermaphroditic duct receives the duct from the mucous gland.

2. The prostate (Figure 8) duct is relatively short, only 100 micra long, and its walls are 20 micra thick. As it emerges from the prostate gland it turns ventrally and anteriorly to open without further change of course into the genital atrium.

3. The receptaculum seminis (Figure 8, *rcp. sem.*) is an elongated sac 85 micra long, 50 micra wide, and 25 micra thick, located on the right side dorsal to the prostate gland and ventral to the kidney chamber. The duct from the receptaculum seminis is 25 micra long and 8 micra thick; it opens into the prostate duct as shown in Figure 8. In copulation, then, the penis enters the prostate duct, which makes it appropriate to designate this duct as the vagina.

4. The oviduct opens with the prostate duct into the genital atrium. From its origin it passes dorsally and to the left until the left side of the body is reached. There it turns anteriorly and then crosses to the right side, this time over the suctorial bulb, finally terminating in the genital atrium. The oviduct (Figure 8, *o'dt.*) is divided into three regions: (1) a terminal, thick-walled, muscular portion 45 micra wide, extending from the prostate duct to the middle region; (2) this is short but much wider, being 60 micra in diameter, and thin walled; it lies over the suctorial bulb; finally (3), the initial part is for 50 micra of its length not more than 30 micra wide. The large cavity in the middle region of the oviduct contains a considerable amount of detritus; the only structures that could be identified were parts of the polyzoan, upon which this species feeds. This region would seem to be, therefore, similar to a spermatheca, although placed in the oviduct. The duct from the albumen gland opens into the oviduct in the last third of its course, about 20 micra from the genital atrium.

5. Penis and vas deferens. A fleshy triangular valve separates the opening of the penis sac from the prostate duct and oviduct. The penis sac, 30 micra wide, may run crosswise in front of the anterior genital mass or back close to the body wall and lateral to the anterior genital mass (Figure 3). The penis has a general width of 10 micra, its end becomes expanded into a head 12 micra wide. The duct running throughout the center of the penis is 4 micra wide and heavily ciliated. Bergh ('**92**, p. 149) states that the penis of Polycerella is armed with hooks. Verrill ('**80**, p. 387), in describing P. emertonii, makes no mention of the reproductive organs. Balch ('**99**, p. 151) says, "No armature of the penis could be made out in sections, but this was perhaps owing to poor preservation." The enlarged end of the penis in P. zoobotryon is unquestionably ciliated and in specimens fixed in four dif-

ferent fluids no evidence of hooks on the penis appeared. Inasmuch as Bergh cites as his only authority Verrill, it is apparent that his statement "penis armata" is a mere supposition based on the fact that it is armed in Polycera. Therefore, this characterization of the genus Polycerella will have to be changed to "penis unarmed."

The vas deferens is a narrow duct of uniform diameter throughout its entire length opening into the prostate duct; it passes by several turns to the base of the penis, the latter part of its course depending upon the position of the penis in the body. The vas deferens is heavily ciliated throughout its whole length.

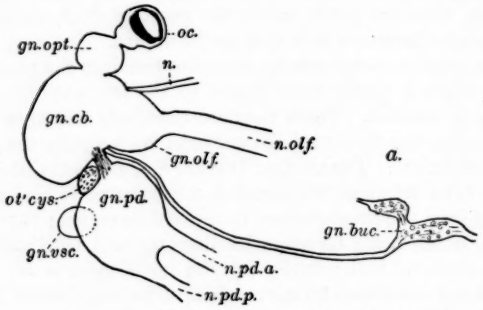

FIGURE 9. Drawing (diagrammatic) of nervous system seen from the right side. *gn.buc.*, buccal ganglion; *gn.cb.*, cerebral ganglion; *gn.olf.*, olfactory ganglion; *gn.opt.*, optic ganglion; *gn.pd.*, pedal ganglion; *gn.vsc.*, visceral ganglion; *n.*, nerve to integument; *n.olf.*, olfactory nerve; *n.pd.a.*, anterior pedal nerve; *n.pd.p.*; posterior pedal nerve; *oc.*, eye; *ot'cys.*, otocyst.

9. *The Nervous System.*

The nervous system is simpler in some respects than it is in the larger Eolidae and in some of the Doridae, although showing the same concentration of the ganglia into a nerve collar around the esophagus immediately behind the pharynx. There are three pairs of large ganglia, — cerebral, pedal, and visceral, — the usual small pair of buccal ganglia, and several minor ganglia to be described afterwards.

The cerebral ganglia (Figures 9, 10, *gn. cb.*) are nearly spherical, the antero-posterior diameter being slightly shorter than the others. They are the largest of the ganglia, each being about 30 by 20 by 20 micra, and cover the dorsal surface and a small part of each side of the esophagus. The cerebral commissure (Figure 10, *co'ms. cb.*) is three micra long and six micra wide. The cerebro-pedal connective (Figure 9)

is short and narrow (5 micra long and 3 micra in diameter), while the cerebro-buccal connective, arising just anterior to the cerebro-pedal connective, is long and slender. Broadly joined to the ventral anterior face of each cerebral ganglion is an olfactory ganglion (Figures 9, 10, *gn. olf.*); a faint constriction is the only external indication of it. The olfactory ganglion is approximately spherical and gradually tapers off into the large (7 micra) nerve (*n. olf.*) that eventually penetrates the base of the rhinophore. With the lateral surface of each cerebral ganglion is connected a spheroidal optic ganglion (*gn. opt.*). As this is sessile on the cerebral ganglion, there is no conspicuous cerebro-optic connective. Joined to the optic ganglion is the simple eye.

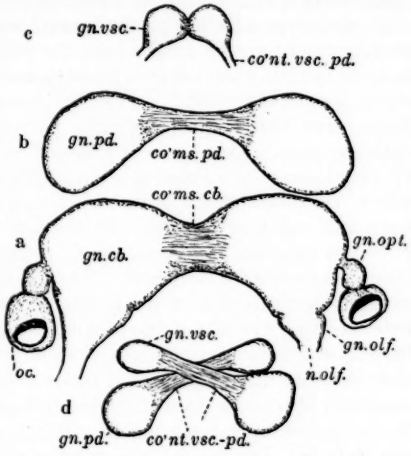

FIGURE 10. Four camera-lucida drawings (a, b, c, d) of the three pairs of ganglia in various positions to show their relative sizes and their connectives and commissures. *co'ms.cb.*, cerebral commissure; *co'ms.pd.*, pedal commissure; *co'nt.vsc.-pd.*, viscero-pedal connective; *gn.cb.*, cerebral ganglion; *gn.olf.*, olfactory ganglion; *gn.opt.*, optic ganglion; *gn.pd.*, pedal ganglion; *gn.vsc.*, visceral ganglion; *n.olf.*, olfactory nerve; *oc.*, eye.

The pedal ganglia lie ventral, and slightly posterior to the cerebral and are somewhat smaller (22 by 20 by 29 micra). The pedal commissure (Figure 9, *co'ms. pd.*) is 20 micra long and 4 micra in diameter; it lies behind and ventral to the cerebro-pedal connectives.

The visceral ganglia (Figures 9, 10) are small (10 by 10 by 10 micra) in comparison with the cerebral and pedal, and lie in close contact with each other. They are situated at the side of, and posterior to, the esophagus back of the pedal commissures. In a frontal section is found an interesting form of connection between the visceral and pedal ganglia (Figure 10, *co'nt. vsc.-pd.*). These connectives are 15 micra long and 4 micra in diameter; they form a distinct chiasma with no apparent mingling of the fibres and clearly show the chiastoneuric affinities of this gasteropod.

The buccal ganglia (Figure 9) are irregular in outline, each ganglion consisting of two parts, the smaller of which lies on the lateral wall of the buccal mass, while the larger is on its ventral surface. The buccal commissure is short, lying on the ventral side of the buccal wall.

Nerves. — In addition to the several commissures and connectives already described, the ganglia have the following nerves. Each of the cerebral ganglia gives off from its posterior surface a small, short nerve which goes to the oviduct. From its dorsal posterior surface arises a large nerve which bends ventrally, passing immediately back of the optic ganglion. This nerve is enlarged on the right side of the body by ganglionic cells. From this ganglionic enlargement some branches pass to the distal portion of the oviduct and penis, others to the lateral body wall and mantle edge. On the left side no corresponding ganglion was detected, the nerve simply giving off many branches to the lateral and posterior body wall. The olfactory portion of the cerebral ganglion is the source of the largest nerve in the body. This nerve extends along the side of the pharynx, sending off to the rhinophore a branch, which spreads out into a wide, much-flattened nerve that is distributed to the integument of the rhinophore. The nerve continues anteriorly beyond the base of the rhinophore giving off several branches to the region around the mouth, while one branch enters the base of the tentacle. Just dorsal and anterior to the olfactory lobe a small nerve (Figure 9, *n.*) arises which goes directly to the integument dorsal to the mouth.

Each pedal ganglion sends to the foot two large nerves, the anterior and posterior pedal nerves. On the right side a third nerve arises from the posterior surface of the right pedal ganglion and goes to the base of the penis.

Each of the visceral ganglia gives off a single nerve which is distributed to the lateral and posterior wall of the pharynx and a small nerve to the anterior genital mass.

10. *Histological Structure of the Pedal Ganglion.*

The several ganglia are essentially like one another histologically, the conditions represented in the pedal ganglion being typical. Each ganglion is closely invested in a connective-tissue capsule. Figure 11 is a longitudinal (parasagittal) section through the right pedal ganglion, showing the cerebro-pedal connective on the left and the origin of the anterior pedal nerve ventrally. There are a few large and many small nerve cells having the base of the cell directed toward the connective-tissue capsule. The number of nerve cells is much less in the ventral

region. Each cell is of the usual unipolar type, and while many send their axons directly into or through the cerebral mass, others send theirs for some distance between other cells before leaving the ganglion. The center of the ganglion is occupied by a feltwork of nerve fibres. Axons in small groups course through this feltwork and pass out into

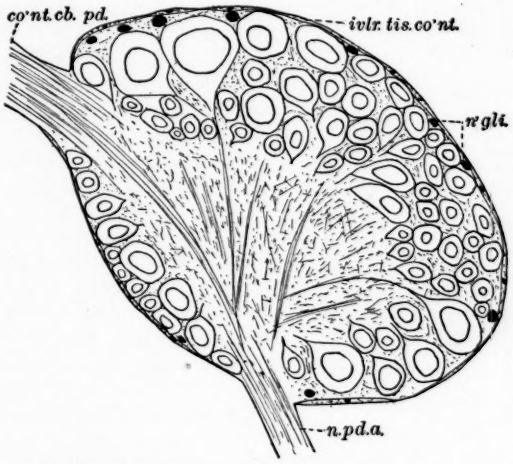

FIGURE 11. Parasagittal section of the right pedal ganglion. *co'nt.cb.-pd.*, cerebro-pedal connective; *ivlr.tis.co'nt.*, connective-tissue sheath; *n'gli.*, neuroglia; *n.pd.a.*, anterior pedal nerve.

the pedal nerve. Axons in the pedal connective can readily be traced through the ganglion into the pedal nerve. The neuroglia cells (Figure 11, *n'gli.*) are few in number and found only around the periphery of the ganglia.

The larger of the nerve cells give a more pronounced reaction to the various reagents than the smaller ones do, although no constant structural differences are observable. The nucleus is proportionately very large and rich in chromatin, while the cytoplasm is finely granular and contains a few vacuoles. In fixation with Hermann's fluid there are a number of blackish bodies in the cytoplasm, and bodies apparently similar are found in the ganglion outside of the nerve cells. Bodies having a similar appearance are also present in the epithelial cells of the reproductive ducts. These bodies are probably fat or related substances blackened by the osmic acid contained in the fixing fluid.

11. *Special Sense Organs.*

Otocyst. — The ear sac (Figure 9, *ot'cys.*) is of an oval outline, its longest diameter being 7.5 micra, and it lies embedded in the dorsal surface of the pedal ganglion. The otokonia are numerous, minute oval bodies not more than 0.6 micron long.

Olfactory organ. — The rhinophore possesses a large nerve that sends off numerous branches during its passage from the base to the tip of the rhinophore. It is difficult to be certain just how the axons of this nerve terminate in the epidermis. The individual branches can be made out at least half way to the surface of the epidermal epithelium, and I am inclined to believe that they simply terminate in free, unmodified fibrils between the epithelial cells. The olfactory nerve sends a branch into the tentacle and several into the region of the lips. Here, also, the individual fibrils appear to end in a similar manner to those in the rhinophore. It is probable that the general snout region, as well as the rhinophores, interprets olfactory stimuli, as both are innervated by a single nerve arising from the olfactory ganglion.

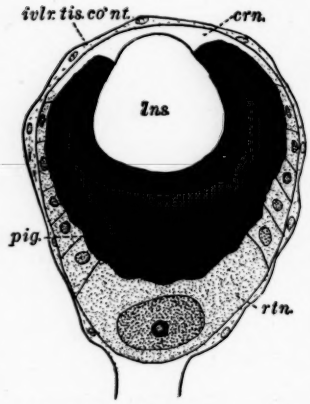

FIGURE 12. Eye. *crn.*, cornea; *ivlr. tis. co'nt.*, connective-tissue sheath; *lns.*, lens; *pig.*, pigment; *rtn.*, retina. Camera lucida, one inch ocular and one-twelfth oil-immersion objective. × 612.

Eye (Figure 12). — The eyes, as already stated in connection with the description of the cerebral ganglia, are in close contact with the optic ganglion. Each eye is completely enveloped in a connective-tissue capsule, which contains a greater amount of connective tissue, nuclei, and fibres than is found in similar tissue surrounding the ganglion. At the base of the eye the capsule is easily traced and is seen to be continuous with that surrounding the ganglion.

Each eye presents, within the cellular capsule, a single layer of cells, which is divisible into an anterior portion, the cornea, and a posterior, the retina. These together completely enclose the lens and a cup-shaped mass of pigment. The lens (Figure 12, *lns.*) is an oval or pear-shaped body completely filling the pigment cup and projecting

somewhat beyond its anterior rim, where it is in contact with the cornea. The pigment (*pig.*) is very dense, consisting of numerous small granules which appear to be located in the retinal cells. At least I was not able to make out the existence of more than this one layer of cells, though it is possible that maceration preparations would have disclosed the presence of other (pigment) cells. The pigment layer is thickest at the bottom of the cup, becoming gradually thinner toward the cup's lips. The cornea and retina apparently consist of only a single layer of cells arranged radially; the cells of the cornea (*crn.*) are much flattened, and stain faintly. The layer contains but few nuclei in front of the lens. The cells become cubical in the region of the retina (*rtn.*), the center of which is occupied by a single large cell with a conspicuous nucleus. Inasmuch as the eyes were not especially fixed and stained for histological study, it was impossible to analyse further the retina or to determine the course of the fibrillae after they enter the retina. Strands of fibrillae were traced from the cerebral into the optic ganglion and thence to the proximal border of the retina.

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